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Response of Sorghum Cultivar's to Nitrogen Levels on Yield, Water Productivity, Stover Nutritive Value Traits and Economic Benefits to Crop-Livestock Farmers in the Semi-Arid Areas of Zimbabwe

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Abstract: An experiment was conducted at Matopos Research Station, Southern Zimbabwe to determine the response of improved sorghum cultivars to nitrogen application rate on two different soil types. Two sweet sorghum cultivars, E36-1 and PVK801 and one grain sorghum variety, Macia were evaluated on clay and sandy soils at 0 (farmers practice), 9 (micro-dosing) and 69 (recommended) kg Nha^{-1}. They were evaluated for yield, water productivity, stover nutritional quality traits and economic benefits. On clay soil, stover yield and water productivity varied significantly ($p<0.05$) across cultivars and nitrogen application rates. The cultivars' stover yield and water productivity were in the order of E36-1 = PVK801>Macia. On sandy soil, cultivars varied significantly ($p<0.05$) for grain yield and water productivity while nitrogen application rates varied significantly ($p<0.05$) for grain and stover yield and water productivity. Clay soil stover Metabolisable Energy (ME) concentration and *in vitro* organic digestibility (IOMD %) were in the order of E36-1 = PVK 801>Macia. The gross margin analysis revealed that higher returns were observed with sweet sorghum cultivars. Sweet sorghum cultivars in combination with higher nitrogen application rates bring more returns to farmers through higher yields, water productivity, improved stover nutritional quality and livelihoods in crop-livestock production systems of semi-arid areas of Zimbabwe.

Key words: Sorghum cultivars, nitrogen, yield, stover quality, gross margin

INTRODUCTION

Crop-livestock farmers in semi-arid areas of Southern Africa are faced with numerous constraints that include poor soil fertility and limited access to high grain and stover yielding cultivars. Crop and livestock productivity is very low in these areas and the situation is further getting worse due to limited availability of land and water (Descheemaeker *et al*., 2011). Over 70% of farmers cultivate on marginal and fragile lands predominantly granitic sands. These soils are inherently infertile have poor structural stability, low water retention and nutrient holding capacity, low organic matter content and low Effective Cation Exchange Capacity (ECEC) and are highly susceptible to land degradation (Grant, 1981). Resources are limited and use of organic manure and application of complementary purchased inputs such as inorganic fertiliser is minimal. Despite increasing adoption of new cultivars of sorghum, millet and maize, productivity remains depressed. While livestock production offers opportunities for risk copying, its productivity is affected by drought, diminishing rangelands, severe overstocking and poor husbandry (Chirima *et al*., 2012; Masikati, 2011). This brings the justification for the urgent need to identify options for improving crop-livestock productivity in order to sustain food security, livelihoods and ecosystem integrity (Faurus and Santini, 2008). To improve production a combination of improved crop varieties, soil fertility, water management, feeding and animal productivity enhancement strategies need to be articulated. Understanding the impacts of these factors require an integrated approach in identifying niches to improve crop-livestock water productivity and soil fertility (Bouman, 2007; Rockstrom and Barron, 2007). Fertiliser applied to crops in micro-dose offer profitable natural resource management technologies with remarkable

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increases in yield (Jensen *et al*., 2003). On-farm experimentation in Zimbabwe confirmed that farmers could increase their yields by 30-100% by applying as little as 9 kg N ha^{-1} (Twomlow *et al*., 2010). Micro-dosing of cultivars that have improved grain, fodder yield and crop residue quality can provide greater benefits than cultivars improved for a single trait.

Sweet sorghum (*Sorghum bicolor* (L.) Moench) is one of the crop options for crop-livestock farmers in semi-arid areas producing higher grain yields and stover of higher quality. The use of sweet sorghum cultivars could increase stover yields and reduce dry season feed shortages that contributes to less livestock products. Hence, farmers would thereby benefit from the increasing demand for livestock products that are forecasted to double by the year 2020 (Delgado *et al*., 1999).

In a previous study, the performance of 20 sweet sorghum cultivars for WP, fodder quality and farmers' preferences was evaluated (Mativavarira *et al*., 2011). The two sweet sorghum cultivars (E36-1 and PVK 801) were among the selected cultivars and are being evaluated in comparison with Macia, sorghum variety for grain, grown by most farmers in Southern African countries. The objectives of this study were to:

- Compare effect of soil types and nitrogen application rates levels on cultivars productivity and stover nutritional quality traits
- Assess the effect of soil types and nitrogen application rates on economic returns of cultivars for grain and stover yields

MATERIALS AND METHODS

Site description: The two trials were carried out at the Matopos Research Station (Longitude 28°46'E; Latitude 20°64'S) during two successive cropping seasons (2008/09 and 2009/10) on two soil types, clay and sandy soil. The clay soil is an imperfectly drained vertisol derived from the igneous or metamorphic rocks and classified as Pelli-Eutric Vertisol (FAO, 1998; Moyo, 2001). The sandy soil is shallow to moderately deep, well drained ferrallitic soil derived from granite and classified as Eutric Arenosol (FAO, 1998; Moyo, 2001). The characteristics of both soils are presented in Table 1 (Moyo, 2001).The site is in agro-ecological region IV characterised by low and erratic rainfall that ranges from 450-650 mm $year^{-1}$. The long-term average rainfall for Matopos Research Station is 590 mm. The rainfall for both seasons is shown in Fig. 1. Rainfall for the 2nd year (2009/10) season was well distributed.

Experimental design and crop management: Sorghum cultivars were tested under different Nitrogen (N) levels in complete randomised blocks, arranged in a split plot design with 3 replicates. In the main plot (22×6 m), three sorghum cultivars (two sweet sorghum (E36-1 and PVK801) and one grain sorghum (Macia)) researchers allocated in the sub-plot (6×6 m), three N levels at top dressing stage were used (0 kg N ha^{-1} (control), 9 kg N ha^{-1} (micro-dosing) and 69 kg N ha^{-1} (recommended)) (Table 2). Trials were planted on two sites the same day. In 1st year, the trials were planted on the 22 December, 2008 while in the 2nd year, they were planted on the 3rd of December, 2009. No basal fertilizer

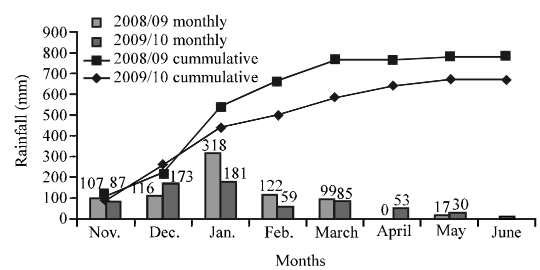

Fig. 1: Monthly and cumulative rainfall (mm) for 2008/09 and 2009/10 seasons

Table 1: Physical and chemical characteristics of clay and sandy soils at Matopos Research Station

Soil characteristics (depth cm)	Clay soil 0-15	Clay soil 15-30	Clay soil 30-45	Sandy soil 0-15	Sandy soil 15-30	Sandy soil 30-45
Clays (%)	41.000	38.000	47.000	4.000	5.000	6.000
Silt (%)	20.000	23.000	17.000	4.000	5.000	4.000
Sand (%)	38.000	39.000	36.000	91.000	91.000	99.000
Gravel (%)	-	-	-	5.000	7.000	8.000
pH ($CaCl_2$)	6.800	7.600	8.000	4.200	4.300	4.300
OC (%)[1]	0.890	0.750	0.710	0.280	0.230	0.160
Ca ($Cmol_c\ kg^{-1}$)	40.200	40.900	32.300	0.800	0.700	3.100
Mg ($Cmol_c\ kg^{-1}$)	14.800	15.400	16.600	1.000	0.700	2.200
K ($Cmol_c\ kg^{-1}$)	1.900	1.800	1.600	0.100	0.100	0.100
Total P (%)	0.042	0.039	0.032	0.040	0.036	0.029
Total N (%)	0.090	0.070	0.040	0.050	0.090	0.030
Avail. N (ppm)	7.042	4.319	1.403	1.042	3.042	1.847
Effective depth (cm)	130.000	-	-	90.000	-	-

[1]OC (%) = Percent Organic carbon where, OC %; *1.724 = OM%; Avail; N = Available Nitrogen

Table 2: Production costs of sorghum under different nitrogen levels (kg N ha^{-1})

				N level (kg N ha^{-1})		
Operations	Unit	Unit costs (USD $)	Quantity	0	9	69
Ploughing services	ha	25.0	1.00	25.00	25.00	25.00
Seed cost	kg	1.0	10.00	10.00	10.00	10.00
Labour costs for other operations	day	2.0	69.06	138.12	138.12	138.12
Fertilizer application labour costs*	day	2.0	6.00	0.00	12.00	12.00
Labour for grain harvesting**	day	2.0	2.27	4.54	7.85	11.51
Bird scaring labour costs***	day	2.0	15.00	30.00	30.00	30.00
Fertilizer cost	kg	0.7	-	0.00	17.50	140.00
Total costs				207.66	240.47	366.63

Mazvimavi and Twomlow (2009): The unit costs used are the market rates; *Labour for fertilizer application at top dressing using spot application is 6 Labour Days (LD); Assumption made is that since the method of application is the same farmers would use the equal LD for different application rates; **Labour for grain harvesting is 2.27 LD which could harvest 868 kg, researchers approximated the LD with observed grain yields for different treatments in gross margin analysis, the labour cost shown in the budget are for harvesting 868, 1500 and 2200 kg at 0, 9 and 69 kg N ha^{-1}, respectively; ***Bird scaring labour days are 0.5 LD day^{-1} for 30 days based on the following assumptions; farmers would scare birds during the most critical periods, i.e., 2 h in the morning and 2 h towards the end of day this would bring to 0.5 LD day^{-1} or farmers with neighbouring fields would rotate for bird scaring and each would have 0.5 LD day^{-1}

was applied at both sites. The land was prepared by conventional ploughing (using a tractor drawn plough) and planting furrows were marked at an interval of 75 cm and seed was drilled continuously in furrows and thinned to 1 plant/station spaced at 20 cm.

Gravimetric soil water was determined by collecting soil samples at planting and maturity. Bulk density determination was done by collecting soil samples by stainless steel cores of 50 mm internal diameter and 50 mm length. Soil samples for bulk density determination were collected before planting from outside the plots but in the same field. The soils were oven dried at 105°C until constant weight was achieved. The gravimetric water content and bulk density were determined for the soil profile depth of 40 cm. Bulk density and gravimetric water content for each 10 cm layer were calculated using the procedure outlined by Anderson and Ingram (1993). Gravimetric water content was converted to volumetric water content for each soil layer. Soil water content (mm) was determined by multiplying volumetric water content by thickness from which the soil water was measured.

The crop was weeded twice after emergence and at vegetative growth stage. Ammonium nitrate (34.5% N) was precision applied at the micro-dosing and recommended rates when the crop was at 6 leaf stage to the selected plots. The control plots were not top dressed. The net plots (5 m×2 rows) were harvested at maturity for grain and stover yield. The stover (above ground biomass minus heads) and sorghum heads were harvested from the net plots. The heads were threshed to record final grain yield. The stover samples of separate leaf and stem parts were oven dried at 60°C up to a constant weight to determine dry weight and a sub sample taken after drying for stover nutritional quality traits analysis. Grains yield was adjusted to 12.5% moisture content based on moisture meter analysis of grain samples (Mupangwa *et al*., 2007).

In this study, Water Productivity (WP) was determined using the procedure of accounting for water use and water productivity (Molden, 1997 or www.unstats.un.org/unsd/envaccounting/ceea/pimeetings/AC-116-10.pdf):

$$\text{WP} = \frac{\text{Output derived from water use}}{\text{Water input}}$$

$$\text{WP (kg DM mm}^{-1}\text{)} = \frac{\text{Grain (12.5\%) / stover yield dry matter (kg DM)}}{\left[\begin{array}{l}\text{(In crop rain fall + (soil moisture at planting} - \\ \text{soil moisture at harvesting)) (mm)}\end{array}\right]}$$

Stover samples were analysed for nitrogen concentration (N concentration × 6.25 = Crude protein concentration), metabolisable energy concentration and *In vitro* Organic Matter Digestibility % (IOMD %) with Infrared Spectroscopy (NIRS; Instrument FOSS Forage Analyzer which utilises WINSI II Software package).

Economic analysis: The economic analysis was derived from a sorghum production budget as described by Mazvimavi and Twomlow (2009) using gross margin analysis of treatments. The grain and stover yields were adjusted by 10% for them to reflect on-farm yields (CIMMYT, 1988).

RESULTS

Yield and water productivity

Clay soil: Sweet sorghum cultivars E36-1 and PVK801 had significantly ($p<0.05$) higher stover yield and water productivity than Macia. Grain yield water productivity varied significantly ($p<0.05$) across the nitrogen levels (Table 3) where differences were observed by increasing nitrogen from 0-69 kg N ha^{-1} (Table 3). There is evidence to show significant stover yield and water productivity with increasing nitrogen levels from 0-9 kg N ha^{-1} and

Table 3: The cultivar agronomic and stover nutritive value traits across nitrogen levels in clay and sandy soil average across years (2008/09 and 2009/10)

	Clay soil							Sandy soil						
	Grain yield	Stover yield	Grain WP	Stover WP	Stover CP	Stover ME	Stover IOMD	Grain yield	Stover yield	Grain WP	Stover WP	Stover CP	Stover ME	Stover IOMD
Value traits	----(kg ha^{-1})----		-----(kg mm^{-1})----		(g kg^{-1})	(mJ kg^{-1})	(%)	-----(kg ha^{-1})-----		----(kg mm^{-1})----		(g kg^{-1})	(mJ kg^{-1})	(%)
Cultivar (C)														
E36-1	3103	3151^{b}	6.67	6.77^{b}	56.1^{a}	7.1^{b}	48.1^{b}	1143^{b}	1478	2.68^{b}	3.48	50.9	7.2	48.7
MACIA	2408	2290^{a}	5.24	4.99^{a}	65.9^{b}	6.7^{a}	46.5^{a}	948^{a}	1241	1.96^{a}	2.54	52.6	6.7	46.3
PVK801	2861	3067^{b}	6.09	6.53^{b}	62.4^{b}	7.2^{b}	48.4^{b}	1158^{b}	1481	2.36^{ab}	3.01	53	7.2	48.1
F-Proba	NS	***	NS	***	***	***	***	***	NS	***	NS	NS	NS	NS
N level (N)														
0 (kg N ha^{-1})	2126	2240^{a}	4.56^{a}	4.83^{a}	58.9^{a}	6.7^{a}	45.9^{a}	711^{a}	1065^{a}	1.49^{a}	2.23^{a}	46.6^{a}	6.8	46.6
9 (kg N ha^{-1})	2826	2908^{b}	5.97^{ab}	6.16^{b}	60.3^{a}	7.0^{b}	47.0^{b}	1024^{b}	1415^{b}	2.12^{b}	2.96^{b}	52.3^{b}	7	47.5
69 (kg N ha^{-1})	3420	3360^{b}	7.48^{b}	7.30^{b}	65.3^{b}	7.3^{c}	50.2^{c}	1514^{c}	1721^{c}	3.4^{c}	3.84^{c}	57.7^{c}	7.3	49
F-Proba	***	NS	NS	NS	***	***	***	***	***	***	***	***	NS	NS
Years														
1	2229^{a}	2331^{a}	4.92^{a}	5.15^{a}	54.6^{a}	7	47.5	525^{a}	711^{a}	0.84^{a}	1.13^{a}	55.8^{b}	7	47.8
2	3352^{b}	3341^{b}	7.08^{b}	7.04^{b}	68.4^{b}	7	48	1642^{b}	2089^{b}	3.84^{b}	4.89^{b}	48.6^{a}	7.1	47.6
F-Prob.	***	***	***	***	***	NS	NS	***	***	***	***	***	NS	NS
Interactions														
C*N; F-Proba	NS	NS	NS	NS	***	***	***	NS	NS	NS	NS	NS	NS	NS
C*Y; F-Proba	NS	NS	NS	NS	***	***	NS	NS	NS	NS	NS	NS	NS	NS
Y*N; F-Proba	NS	NS	NS	NS	NS	NS	NS	NS	NS	***	NS	NS	NS	NS
C*N*Y; F-Proba	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
CV%	33	23	33	24	7	3	4	31	30	32	15	9	8	7

NS = Not Significantly different at 5% LSD; ***Significantly different at 5% LSD; Mean with different letters show significant differences at $p<0.005$

beyond that level to 69 kg N ha^{-1} no significant increases were observed. Year 1 had significantly lower grain and stover yield and water productivity than year 2 (Table 3). The grain water productivity for year 1 and 2 were 4.92 and 7.08 kg mm^{-1}, respectively. No significant ($p>0.05$) year by nitrogen by cultivar (Y*N*C) interaction was observed for grain and stover yield, generally sweet sorghum cultivars E36-1 and PVK 801 out-performed Macia.

Sand soil: Grain yield and water productivity varied significantly ($p<0.05$) across cultivars, nitrogen levels and seasons (Table 3). Sweet sorghum cultivars E36-1 and PVK801 had significantly higher grain yields of 1143 and 1158 kg ha^{-1}, respectively than Macia with 948 kg ha^{-1} (Table 3). Grain and stover yield and water productivity varied significantly ($p<0.05$) across nitrogen levels in the order of 69>9>0 kg N ha^{-1} (Table 3). Grain yield for season 1 and 2 were 525 and 1642 kg ha^{-1}, respectively while stover yields were 711 and 2089 kg ha^{-1}, respectively (Table 3). No significant year by nitrogen by cultivar (Y*N*C) interaction was observed for grain and stover yield.

Stover nutritive value traits

Clay soil: Cultivars had significant differences ($p<0.05$) for Crude Protein (CP) concentration (Table 3) where Macia and PVK801 had significantly ($p<0.05$) higher CP concentrations of 65.89 and 62.43 g kg^{-1} DM, respectively (Table 3). Nitrogen levels increased CP concentration significantly from 60.25-65.31 g kg^{-1} DM as

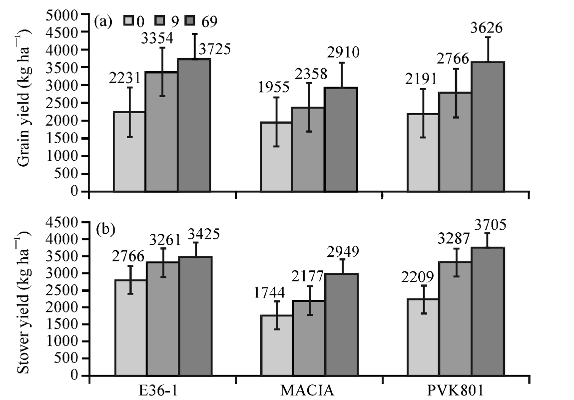

Fig. 2: Interaction of sorghum cultivars and nitrogen level on: a) grain; b) stover yield (error bars shows ±5% Lsd) in clay soil

nitrogen was increased from 9-69 kg N ha^{-1}. CP concentration varied significantly ($p<0.05$) across the years (Table 3). Significant cultivar by nitrogen level (C*N) and cultivars by year (C*Y) interaction were observed on CP concentration were Macia had higher CP concentration across N levels and years (Fig. 2). Metabolisable Energy (ME) concentration and *In vitro* Organic Matter Digestibility (IOMD) % were significantly different ($p<0.05$) across cultivars and nitrogen levels (Table 3). Sweet sorghum cultivars E36-1 and PVK801 had significantly higher ME content and IOMD % than Macia (Table 3). There was significant ($p<0.05$) cultivars by nitrogen (C*N) and cultivars by year (C*Y) interaction on ME concentration. IOMD % had significant ($p<0.05$)

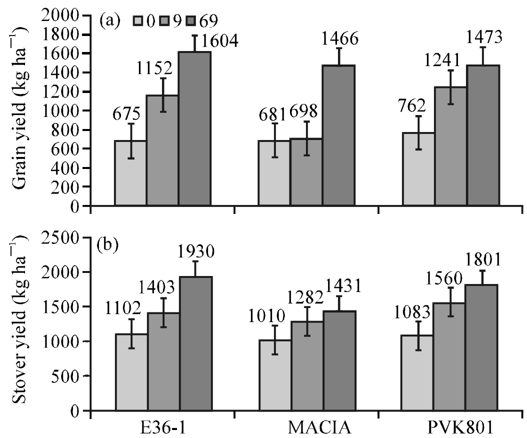

Fig. 3: Interaction of sorghum cultivars and nitrogen level on: a) grain; b) stover yield (error bars shows ±5% Lsd) in sandy soil

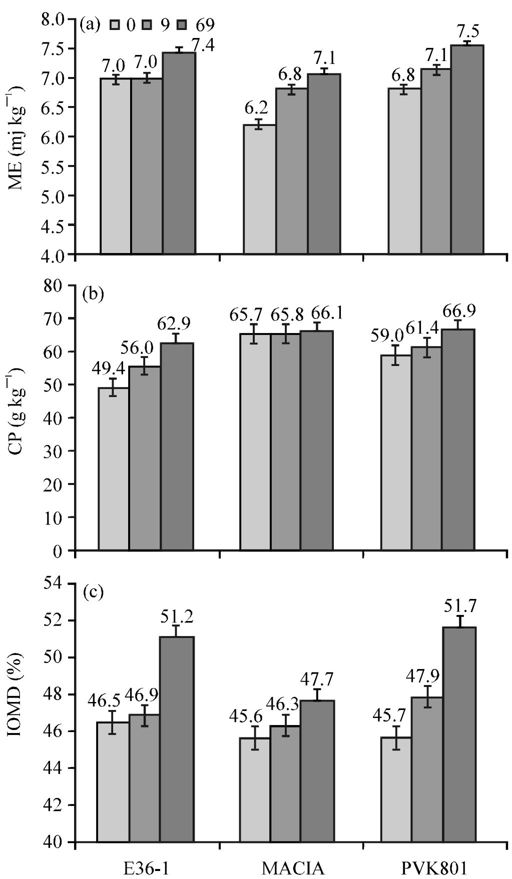

Fig. 4: Interaction of sorghum cultivars and nitrogen level on: a) Metabloisable Energy (ME); b) Crude Protein (CP); c) *In vitro* Organic Matter Digestibility % (IOMD %) (error bars shows ±5% Lsd) in sandy soil

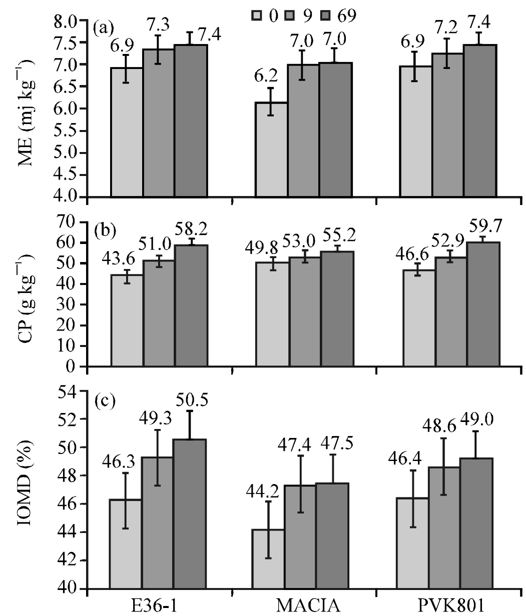

Fig. 5: Interaction of sorghum cultivars and nitrogen level on: a) Metabolisable Energy (ME); b) Crude Protein (CP); c) *In vitro* Organic Matter Digestibility % (IOMD %) (error bars shows ±5% Lsd) in clay soil

cultivar by nitrogen level (C*N) interaction (Table 3). The sweet sorghum cultivar had significantly higher ME and IOMD % across N levels (Fig. 2).

Sand soil: Crude protein concentration varied significantly ($p<0.05$) across nitrogen application levels (Table 3). The highest CP concentration of 57.66 g kg^{-1} DM was observed at 69 kg N ha^{-1} (Table 3). CP concentration varied significantly ($p<0.005$) across the years with the highest CP concentration of 55.83 g kg^{-1} DM observed in the 1st year (Table 3). No significant cultivar by nitrogen levels (C*N) interaction ($p>0.05$) was observed on stover nutritional quality traits (Table 3 and Fig. 3).

Nitrogen level's relationship with traits: The regression analysis showed a very strong relationship on the response of grain and stover yield to nitrogen fertilizer application rates. The R^2 of all the cultivars on both soils was >0.50. On both soils sorghum cultivars sweet sorghum cultivars; E36-1 and PVK801 were superior to Macia on grain and stover yield response to nitrogen (Fig. 4 and 5). The response to nitrogen fertilizer application level suggest that high grain and stover yields could be realized at 40 kg N ha^{-1} on both soils.

There was a positive response of sorghum cultivars to nitrogen application level in respect to stover nutritive

Table 4: Gross margin analysis of sorghum cultivars production on clay and sandy soils at three nitrogen levels (kg N ha^{-1}) based on average grain and stover yield in the 2008/09 and 2009/10 seasons

		Clay soil ($)			Sandy soil ($)		
Cultivar	N level	Production costs	Income	Gross margin	Production costs	Income	Gross margin
E36-1	0	230.53	841.44	610.91	213.03	287.12	74.09
	9	268.34	1154.86	886.52	246.62	431.39	184.77
	69	393.59	1258.47	864.87	374.47	597.76	223.29
Macia	0	222.98	653.91	430.93	212.50	277.18	64.68
	9	257.03	797.73	540.70	245.40	393.59	148.19
	69	386.85	1016.67	629.83	370.77	505.47	134.70
PVK 801	0	226.94	764.08	537.14	213.33	304.36	91.04
	9	265.73	1025.75	760.02	248.00	470.68	222.68
	69	394.84	1270.55	875.72	373.06	552.46	179.39

Market price of stover = $1.5/11 kg bail; Grain price is $250.00 ton^{-1}; Stover cutting costs $7.2/1060 kg

value traits. The sweet sorghum cultivar's showed a highly positively correlated (R^2>0.5) response of all stover nutritive value traits on both soils while Macia was loosely positively correlated (R^2<0.5) on ME and IOMD %. The response suggest high stover nutritive value traits at 40 kg N ha^{-1} with sweet sorghum cultivars superior to Macia on ME and IOMD % on both soils.

Gross margin analysis: In increasing order of production cost due to fertilizer N application levels could be ranked from 0, 9 and 69 kg ha^{-1} (Table 4). The results of gross margin analysis of nitrogen levels and cultivars show that the highest returns on grain and stover yields were realised with E36-1 on both clay and sandy soils (Table 4). The highest gross margin on sandy soils was on both PVK801 at micro-dosing N level and E36-1on clay soil at micro-dosing. These results show that higher returns of fertilizer use could is on sweet sorghum cultivars.

DISCUSSION

Study site and rainfall pattern: Sandy soil generally had a low Organic Carbon (OC), pH and available N than clay soil (Table 1). The low OC could be attributed to inability of the soil to protect the OM from microbial attack (Okalebo *et al*., 1993) and continuous cultivation, exposing organic carbon pools to aeration and subsequent mineralisation (Liu *et al*., 2006). Under low soil organic matter, the soil system of the sandy soil was susceptible to drought due to poor structural stability and low water holding capacity (Bationo and Mokwunye, 1991). Low organic matter levels also affected efficacy of applied fertiliser and nutrient acquisition. This is because OC also determines the response to nitrogen, affects P dynamics in addition to P release by soil minerals. Further, competition of organic legends for Fe and Al under acidic conditions (low pH) possibly resulted in P fixation affecting N uptake. These conditions possibly effected root plant growth, seed formation leading to low yields and water productivity observed in this study (Table 3) (Vanlauwe, 2004).

The total season rainfall received in both farming seasons was above the site's 50 years average rainfall of 590 mm; 2008/09 season received 779.5 mm while 2009/10 season received 667.8 mm between November and June. Poor rainfall distribution during the 2008/09 season negatively impacted sorghum growth at both soils as the crop was water logged in January (317.6 mm) for between 2-3 weeks. The crop also matured under residual soil moisture (Fig. 1). These might partly be the contributing factors to lower grain and stover yields observed in the first season at both soil types. This is because water logging has shown to affect primary root length, shoot dry weight, leaf dry weight and development of plant height (Promkhambut *et al*., 2011). The impact of these factors was higher on sandy soil than clay soil as the soil is inherently infertile.

Yield and water productivity: Sweet sorghum cultivars have shown superiority over grain cultivar for stover yield and water productivity in clay soil. This reflects sensitivity of the crop to the nature of the soil under which it is grown. The study reflects that productivity of sweet sorghum cultivars can only be targeted for stover under heavily textured soils. Under sandy soils, economic benefits can be derived from improved grain yield and water productivity with the same cultivar. The increase in grain and stover yield and water productivity in response to higher N application levels could be attributed to faster root and shoot development which promotes effective water and nutrient uptake (Gaiser *et al*., 2004). Fertilizer application at recommended level in clay soil was not economically profitable in this study. The law of diminishing returns is quite evident in this study in conjunction with the effects from a one-sided depressing productivity. On sandy soil, yield and water productivity increases observed from the recommended dose suggests mitigation of the inherently deficient N pools (Zingore *et al*., 2007). These results concur with yield increases observed due to micro-dosing in previous studies (Twomlow *et al*., 2010).

Stover nutritional traits nutritive value: In clay soil sweet sorghum cultivars had superiority in stover nutritional traits as seen by higher Metabolisable Energy (ME) concentration and *In vitro* Organic Matter Digestibility (IOMD %). The C*N interaction observed for Crude Protein (CP) concentration showed that Macia was superior to other cultivars at all N levels and across years (Table 3 and Fig. 2). Based on these CP levels results show that even though sorghum stover is of poor nutritive value relative to animal requirements, it is superior to rangelands during the dry season where CP falls to 20-40 g kg^{-1} DM (Blummel *et al*., 2009; Topps and Oliver, 1993). In both soils, an increase in nitrogen levels lead to higher stover nutritive value traits (Reddy *et al*., 2003). The ME was increased from 6.7 and 6.8 mJ kg^{-1} DM to 7.0 and 7.0 mJ kg^{-1} DM in clay and sandy soils, respectively due to micro-dosing on sweet sorghum cultivars. Which is the minimum ME for livestock maintenance requirements (Topps and Oliver, 1993). Hence, the evaluated sweet sorghum cultivars are able to provide maintenance energy unlike Macia. In clay soil, the cultivar and nitrogen (C*N) interaction on ME and IOMD % shows that sweet sorghum cultivars had higher response to nitrogen application rates than Macia. Increases of >3% in IOMD % where observed in clay soil by increasing N level to 69 kg N ha^{-1} and also by selecting sweet sorghum cultivars at 69 kg N ha^{-1} instead of Macia (Table 3). These kind of differences intuitively appear small, however such differences were associated with price premiums of 25% and higher in sorghum stover trading in India (Blummel and Rao, 2006).

Gross margin analysis: In clay soils the highest gross margin could are observed with micro-dosing while in sandy soils highest Gross Margin (GM) are with recommended N application rates. Based on cultivar choose the sweet sorghum cultivar E36-1 had the highest returns to fertilizer use on both soils.

CONCLUSION

The sweet sorghum cultivars when grown in dry environments of Zimbabwe are economically beneficial in terms of stover feed quantity and grain yield in clay and sandy soil, respectively. According to the prevailing study, they are an attractive alternative for adaptation to climate change due to higher water productivities. Higher ME and IOMD % in both soils suggest that sweet sorghum cultivars could also reduce feed nutritive value deficits under climate risks. A remarkable yield can be achieved with micro-dosing under clay soils and a high application N rate will enhance viability under sandy soils. The gross margin analysis showed that crop-livestock farmers would realise more financial returns from E36-1 on both clay and sandy soils.

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